ALTITUDE PHYSIOLOGY

Ref. FM 1-300

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GASES OF THE ATMOSPHERE

- 78% NITROGEN
- 20.9% OXYGEN
- 1.1% ARGON, CO2, NEON, HELIUM, KRYPTON, XENON, HYDROGEN, AMMONIA

ATMOSPHERIC PRESSURE

- TROPOSPHERE: S.L. TO 30,000’ AT THE NORTH & SOUTH POLES; 60,000’ AT THE EQUATOR
- WHERE MOST ARMY FLIGHTS TAKE PLACE

STANDARD PRESSURE/TEMP

S.L.	29.92	15C	1 ATM
10,000	20.58	-4.8C	
18,000	14.95	-20.7C	1/2 ATM
20,000	13.76	-24.6C	
25,000	10.51	-34.5C	
30,000	8.90	-44.4C	
34,000	7.40	-52.4C	1/4 ATM

COMPONENTS & FUNCTION OF BLOOD

- 55% PLASMA: TRANSPORTS CO2, NUTRIENTS, AND HORMONES
- 45% CELLS: RED BLOOD CELLS TRANSPORT OXYGEN; WHITE BLOOD CELLS FIGHT INFECTION; PLATELETS CLOT BLOOD

RESPIRATION

- EXCHANGE OF BLOOD GASES OCCURS IN THE ALVEOLI OF THE LUNGS
- OXYGEN & CO2 MOVE IN AND OUT OF ALVEOLI DUE TO PRESSURE DIFFERENTAILS BETWEEN THEIR LEVELS AND THE SURROUNDING CAPILARIES
- THIS PRESSURE DIFFERENTIAL IS CRITICAL TO THE CREW MEMBER BECAUSE OXYGEN SATURATION IN THE BLOOD DECREASES AS ALTITUDE INCREASES.

HYPOXIA

WAR STORIES?

TYPES OF HYPOXIA

- HYPOXIC
- HYPEMIC
- STAGNANT
- HISTOTOXIC

HYPOXIC HYPOXIA

- ASSOCIATED WITH HIGH ALTITUDE
- LACK OF AVAILABLE OXYGEN
- REDUCED OXYGEN PRESSURE IN LUNGS
- AR 95-1 LIMITS TIME AT HIGH ALT.

HYPEMIC HYPOXIA

- REDUCED OXYGEN CARRYING CAPACITY OF THE BLOOD
- ANEMIA & BLOOD LOSS ARE MOST COMMON CAUSES
- CO, NITRITES & SULFA DRUGS CAN ALSO REDUCE AVAILABLE HEMOGLOBIN

STAGNANT HYPOXIA

- INADEQUATE CIRCULATION
- HEART FAILURE, ARTERIAL SPASM & BLOOD VESSEL OCCLUSION
- VENOUS POOLING DURING HIGH G MANEUVERS

HISTOTOXIC HYPOXIA

- INTERFERENCE WITH USE OF OXYGEN BY BODY TISSUES
- ALCOHOL, NARCOTICS, CERTAIN POISONS (CYANIDE)

SIGNS AND SYMPTOMS

- SIGNS (OBJECTIVE)
- HYPERVENTILATION
- CYANOSIS
- MENTAL CONFUSION
- POOR JUDGMENT
- MUSCLE INCOORDINATION

- SYMPTOMS (SUBJECTIVE)
- AIR HUNGER
- APPREHENSION
- FATIGUE
- NAUSEA
- HEADACHE
- DIZZINESS
- HOT AND COLD FLASHES
- EUPHORIA
- BELLIGERENCE
- BLURRED VISION
- TUNNEL VISION
- NUMBNESS, TINGLING

INDIVIDUAL DIFFERENCES IN SUSCEPTIBILITY TO HYPOXIA

- ONSET TIME & SEVERITY VARY WITH INDIVIDUALS
- SELF IMPOSED STRESS (SMOKING, ALCOHOL)
- INDIVIDUAL FACTORS (METABOLIC RATE, DIET, NUTRITION, EMOTIONS)
- ASCENT RATE (DURING RAPID ASCENT CAN REACH HIGH ALT. BEFORE SERIOUS SYMPTOMS ARE NOTICED)
- EXPOSURE DURATION
- AMBIENT TEMPERATURE (TEMP. EXTREMES INCREASE METABOLIC RATE)
- PHYSICAL ACTIVITY INCREASES OXYGEN DEMAND
- PHYSICAL FITNESS (GOOD FITNESS EQUALS HIGHER TOLERANCE)

STAGES OF HYPOXIA

- INDIFFERENT
- COMPENSATORY
- DISTURBANCE
- CRITICAL

INDIFFERENT STAGE

- 0’ - 10,000’
  - (98-90% O2 SATURATION)
- ONLY EFFECT OF THIS MILD FORM OF HYPOXIA IS THAT NIGHT VISION DETERIORATES ABOVE 4000’

COMPENSATORY STAGE

- 10,000’ - 15,000’
  - (90-80% O2 SATURATION)
- DROWSINESS
- POOR JUDGMENT
- IMPAIRED COORDINATION
- IMPAIRED EFFICIENCY

DISTURBANCE STAGE

- 15,000’ - 20,000’
- (80-70% O2 SATURATION)
- IMPAIRED FLIGHT CONTROL
- IMPAIRED HANDWRITING
- IMPAIRED SPEECH
- DECREASED COORDINATION
- IMPAIRED VISION
- DECREASED SENSATION TO PAIN
- IMPAIRED INTELLECTUAL FUNCTION
- DECREASED MEMORY
- IMPAIRED JUDGMENT

CRITICAL STAGE

- 20,000’ - 25,000’
  - (70-60% O2 SATURATION)
- CIRCULATORY FAILURE
- CNS FAILURE
- CONVULSIONS
- CARDIOVASCULAR COLLAPSE
- DEATH

PREVENTION OF HYPOXIC HYPOXIA

- LIMIT TIME AT ALTITUDE
  - AR 95-1 LIMITS 1 HR. ABOVE 10,000', 30 MIN. ABOVE 12,000' AND NO FLIGHTS ABOVE 14,000' WITHOUT SUPPLEMENTAL OXYGEN
- USE SUPPLEMENTAL O2
  - RECOMMENDED ON NIGHT FLIGHTS ABOVE 4,000'
- PRESSURIZATION OF CABIN

TREATMENT OF HYPOXIA

- GIVE 100% O2 THROUGH MASK
- IF O2 IS NOT AVAILABLE, DESCENT BELOW 10,000’ IS MANDATORY
- IF SYMPTOMS PERSIST, TYPE AND CAUSE MUST BE DETERMINED, AND TREATMENT ADMINISTERED

HYPERVENTILATION

HYPERVENTILATION CHARACTERISTICS

- DEFINITION: EXCESSIVE RATE AND DEPTH OF RESPIRATION LEADING TO ABNORMAL LOSS OF CO2 FROM THE BLOOD
- SELDOM INCAPACITATES, CAUSES DISTURBING SYMPTOMS WHICH CAN FURTHER AGGRAVATE BREATHING RATE AND ANXIETY

HYPERVENTILATION CAUSES

- EMOTIONS: WHEN FEAR, ANXIETY OR STRESS ALTERS NORMAL BREATHING PATTERN, INDIVIDUAL MAY ATTEMPT TO CONTROL BREATHING. RESPIRATION RATE IS LIKELY TO INCREASE WITHOUT ELEVATED CO_2 PRODUCTION RESULTING IN HYPERVENTILATION

CAUSES CONT'D

- PRESSURE BREATHING
- HYPOXIA: WHEN HYPOXIA OCCURS AND O2 LEVEL DECREASES, THE RESP. CENTER TRIGGERS AND INCREASE IN BREATHING RATE. THIS INCREASE, BENEFICIAL FOR O2 UPTAKE, CAUSES EXCESSIVE LOSS OF CO2 WHEN CONTINUED FOR TOO LONG

SIGNS & SYMPTOMS OF HYPERVENTILATION

- EXCESSIVE LOSS OF CO_2 AND RESULTANT CHEMICAL IMBALANCE PRODUCE THE FOLLOWING:
- DIZZINESS
- MUSCLE SPASMS
- UNCONSCIOUSNESS
- VISUAL IMPAIRMENT
- TINGLING SENSATIONS
- HOT AND COLD SENSATIONS

DISTINGUISHING BETWEEN HYPERVENTILATION & HYPOXIA

- HYPERVENTILATION: NERVE AND MUSCLE IRRITABILITY, INTERMITTENT MUSCULAR CONTRACTIONS, AND INCREASED BREATHING RATE. USUALLY OCCURS BELOW 10,000’
- HYPOXIA: CAUSES CYANOSIS (BLUENESS OF SKIN), IMPAIRED VISUAL ACUITY, HEADACHE AND DROWSINESS. USUALLY OCCURS ABOVE 10,000’

TREATMENT OF HYPERVENTILATION

- BEST METHOD IS TO VOLUNTARILY REDUCE RATE OF BREATHING, HOWEVER APPREHENSION MAY HAMPER THAT EFFORT
- NORMAL RATE IS 12-16 BREATHS PER MINUTE
- AVOID PANIC
- GO TO 100% O2 (IF AVAILABLE)
- TALK OR SING (TO ELEVATE CO2 LEVEL)
- IF SEVERE OR COMBINED WITH HYPOXIA, RETURN TO GROUND LEVEL

PRESSURE CHANGE

EFFECTS

DYSBARISM

- THE HUMAN BODY CAN WITHSTAND ENORMOUS CHANGES IN BAROMETRIC PRESSURE AS LONG AS AIR PRESSURE IN THE BODY CAVITIES EQUALS AMBIENT AIR PRESSURE
- DYSBARISM IS VARIOUS MANIFESTATIONS OF GAS EXPANSION INDUCED BY DECREASED BAROMETRIC PRESSURE
- THESE MANIFESTATIONS CAN BE JUST AS DANGEROUS, OR MORE SO, THAN HYPOXIA OR HYPERVENTILATION

TRAPPED GAS DISORDERS

- DURING ASCENT, FREE GAS NORMALLY PRESENT IN VARIOUS BODY CAVITIES EXPANDS. IF THE ESCAPE OF THE EXPANDED VOLUME IS IMPEDED, PRESSURE BUILDS UP WITHIN THE CAVITY AND PAIN IS EXPERIENCED. THIS ACCOUNTS FOR ABDOMINAL, EAR, SINUS PAIN OR TOOTHACHE

BOYLE'S LAW

- STATES THAT THE VOLUME OF A GAS IS INVERSELY PROPORTIONAL TO THE PRESSURE EXERTED UPON IT
- DRY GAS CONDITIONS: THE ATMOSPHERE IS NOT SATURATED WITH MOISTURE (COMMON AT HIGH ALT), GAS EXPANDS AS PRESSURE DECREASES
- WET GAS CONDITIONS: GASES WITHIN THE BODY ARE SATURATED WITH WATER VAPOR. UNDER CONSTANT TEMP AND AT THE SAME ALT AND PRESSURE THE VOLUME OF WET GAS IS GREATER THAN DRY GAS. (ABOUT 1.2 TIMES GREATER)

TRAPPED GAS DISORDERS OF THE GASTROINTESTINAL TRACT

- AT LOW OR INTERMEDIATE ALTITUDES SYMPTOMS ARE NOT SERIOUS IN MOST INDIVIDUALS
- ABOVE 25,000’ ENOUGH DISTENSION MAY OCCUR TO PRODUCE SEVERE PAIN
- RELIEF: “BELCHING OR PASSING FLATUS”

TRAPPED GAS DISORDERS OF THE EARS

- AS BAROMETRIC PRESSURE IS REDUCED DURING ASCENT, THE EXPANDING AIR IN THE MIDDLE EAR IS INTERMITTENTLY RELEASED THROUGH THE EUSTACHIAN TUBE
- WHEN PRESSURE IS RELEASED THERE IS OFTEN A “CLICK” OR “POP”

DURING FLIGHT

- DURING DESCENT, THE CHANGE IN PRESSURE WITHIN THE EAR MAY NOT OCCUR AUTOMATICALLY
- EUSTACHIAN TUBE ALLOWS AIR TO PASS OUTWARD EASILY BUT RESISTS PASSAGE IN THE OPPOSITE DIRECTION
- IF DESCENT IS CONTINUED, IT MAY BE IMPOSSIBLE TO CLEAR THE EAR, RESULTING IN PAIN
- IF THE PAIN INCREASES, RELIEF CAN ONLY BE OBTAINED BY ASCENT TO A LEVEL AT WHICH THE PRESSURE CAN BE EQUALIZED

COMPLICATIONS FROM PRE-EXISTING CONDITIONS

- RESPIRATORY INFECTIONS!
- WORSENS WHEN THE EUSTACHIAN TUBE IS SWOLLEN DUE TO HEAD COLD, SORE THROAT, INFECTION OF MIDDLE EAR, SINUSITIS, OR TONSILLITIS
- IN THESE CASES, FORCEFUL OPENING OF THE EUSTACHIAN TUBE MAY CARRY INFECTION INTO THE MIDDLE EAR
- CREW MEMBERS WHO HAVE COLDS AND SORE THROATS SHOULD NOT FLY UNLESS IT IS ABSOLUTELY NECESSARY

PREVENTION AND TREATMENT

- NORMALLY, PRESSURE CAN BE EQUALIZED DURING DESCENT BY SWALLOWING, YAWNING, OR TENSING THE THROAT MUSCLES
- IF UNABLE, PERFORM THE VALSALVA MANEUVER
- *NOTE: TO AVOID OVERPRESSURIZATION, DO NOT VALSALVA DURING ASCENT*

TRAPPED GAS DISORDERS OF THE SINUSES

- CAUSE: SINUS OPENINGS MAY BECOME OBSTRUCTED WHEN THE MUCOUS MEMBRANE LINING SWELLS AS A RESULT OF AN INFECTION OR ALLERGIC CONDITION. UNLIKE THE EARS, THE SINUSES ARE ALMOST EQUALLY AFFECTED BY ASCENT AND DESCENT.

SINUSES CONT'D

- PREVENTION: AVOID FLYING WITH A COLD OR CONGESTION. DURING DESCENT, PERFORM THE VALSALVA MANEUVER FREQUENTLY. (SINUS OPENINGS ARE SMALLER THAN THE EUSTATION TUBES) IF PAIN IS EXPERIENCED DURING ASCENT, AVOID ANY FURTHER INCREASE IN ALTITUDE

SINUS CONT'D

- TREATMENT: IF SINUS BLOCK OCCURS DURING DESCENT, STOP AND ATTEMPT A FORCEFUL VALSALVA MANEUVER. IF UNABLE TO CLEAR, CLIMB TO A HIGHER ALTITUDE, THEN PERFORM VALSALVA DURING A SLOW DESCENT TO THE GROUND. IF PRESSURE DOES NOT EQUALIZE, CONSULT THE FLIGHT SURGEON AFTER LANDING.

TRAPPED GAS DISORDERS OF THE TEETH

- CHANGES IN BAROMETRIC PRESSURE CAN CAUSE TOOTHACHE, USUALLY RESULTING FROM AN EXISTING DENTAL PROBLEM. (GUM OR ROOT ABSCESS, INFLAMED PULP OR MAXILLARY SINUS) ONSET USUALLY OCCURS FROM 5,000’-15,000’. DESCENT ALMOST ALWAYS BRINGS RELIEF AT THE SAME ALTITUDE THE PAIN BEGAN.

EVOLVED GAS DISORDERS

- OCCUR IN FLIGHT AS A DIRECT RESULT OF REDUCED ATMOSPHERIC PRESSURE. CAUSE VARIOUS SKIN AND MUSCLE SYMPTOMS, SOMETIMES FOLLOWED BY NEUROLOGICAL SYMPTOMS. (ALSO KNOWN AS DECOMPRESSION SICKNESS)

HENRY'S LAW

- SIMILAR TO GASES BEING HELD UNDER PRESSURE IN A SODA BOTTLE. WHEN THE CAP IS REMOVED, THE LIQUID IS SUBJECT TO A PRESSURE LESS THAN THAT REQUIRED TO HOLD THE GASES IN SOLUTION; GASES ESCAPE IN THE FORM OF BUBBLES. NITROGEN IN THE BLOOD ACTS IN THE SAME MANNER.

- CONT'D
- INERT GASES IN THE BODY TISSUES ARE EQUAL TO THE PARTIAL PRESSURES OF THE SAME GASES IN THE ATMOSPHERE. WHEN BAROMETRIC PRESSURE DECREASES, THE PARTIAL PRESSURES OF ATMOSPHERIC GASES DECREASES PROPORTIONALLY. THIS CAUSES THE TISSUES TO BECOME SUPERSATURATED, THE BODY ATTEMPTS TO EQUALIZE BY TRANSPORTING THE EXCESS GAS VIA VENOUS BLOOD TO THE LUNGS.